IMPLICATIONS OF OCEAN INTERIOR CO_2 AND $^{14}CO_2$ FOR AIR-SEA GAS EXCHANGE PARAMETERIZATIONS

A.R. Jacobson[1], M. Gloor[1], C. Sweeney[2], R.M. Key[1], N. Gruber[3], and J.L. Sarmiento[1]

[1]*Program in Atmospheric and Oceanic Sciences, Princeton Univ., Princeton, Princeton, NJ, 08544-0710*; *andyj@splash.princeton.edu; emg@splash.princeton.edu; jls@princeton.edu*

[2]*CIRES, University of Colorado at Boulder, 216 UCB Room 318, Boulder, CO 80309-0216; Colm.Sweeney@noaa.gov*

[3] *IGPP & Department of Atmospheric and Oceanic Sciences, UCLA, 5839 Slichter Hall, Los Angeles, CA 90095; ngruber@igpp.ucla.edu*

BACKGROUND

In recent years our knowledge of gas exchange across the air-sea interface at the process level has improved as a consequence of new instrumentation and novel use of injected and natural tracers. However, there remains significant uncertainty in the extrapolation of these results to larger scales, especially for studies focusing on global-scale processes such as the earth's carbon cycle. For such large-scale studies, fluxes F of carbon dioxide are generally assumed to be proportional to solubility S and air-sea partial pressure difference ΔpCO_2. by a gas transfer velocity, k:

$$F = k\, S\, \Delta p\mathrm{CO}_2. \qquad (1)$$

The observed dependence of the gas transfer velocity on surface turbulence--and hence, surface wind speeds--at small scales is generally assumed to scale to large scales by considering the statistical distribution of wind speeds. The most commonly used parameterizations are also forced to agree with the observational constraint on long-term gas exchange imposed by the ocean's inventory of bomb radiocarbon [*Wanninkhof*, 1992; *Wanninkhof and McGillis*, 1999].

The validity of the assumptions involved in this upscaling is difficult to assess because of the lack of independent constraints on gas exchange at global scales. Furthermore, the ocean inventory of bomb radiocarbon is in dispute [*Key et al.*, 2004; see also the contribution by *Sweeney et al.* in this volume]. As a result, air-sea gas parameterizations are still quite uncertain. This is exemplified by large discrepancies in estimates of the globally integrated uptake of anthropogenic carbon by the oceans using different parameterizations of the gas transfer velocity as a function of wind speed, which range from 1 to 3 PgC yr^{-1} for 1995 [*Feely et al*. 2001].

APPROACH

We have recently developed inverse methods that permit us to estimate air-sea fluxes of CO_2 and from ocean interior data and models of ocean transport [*Gloor et al.* 2001]. Notably, these flux estimates do not use surface observations of atmosphere-ocean partial pressure differences. Thus k in (1) can be isolated by considering observational estimates of ΔpCO_2. and solubilities computed from climatologies. We thus have monthly climatological estimates of spatially-varying gas transfer velocity k which can be compared with wind speed estimates from numerical weather prediction reanalysis efforts. We will assess the consistency of current gas transfer velocity parameterizations with the new large scale flux constraint, and discuss possible forms that a new k parameterization may take.

Similar inversion methods have been used to compute estimates of bomb radiocarbon ($^{14}CO_2$) fluxes across the air-sea interface [see *Sweeney et al.*, this volume]. The resulting inventory estimates are lower by about 25% than those of Broecker *et al.* [1995), and suggest that gas transfer velocities may be overestimated by as much as 50% using traditional parameterizations. The inconsistency between this result and the contemporary understanding of ocean carbon cycling embodied by ΔpCO_2-based flux climatologies [e.g., *Takahashi et al.*, 2002] indicates that significant uncertainties remain in our understanding of the mechanisms driving large scale air-sea gas exchange.

REFERENCES

Broecker, W.S., S. Sutherland, W. Smethie, T.H. Peng, and G. Ostlund, Oceanic Radiocarbon - Separation of the Natural and Bomb Components, *Global Biogeochemical Cycles*, *9* (2), 263-288, 1995.

Feely, R.A., C.L. Sabine, T. Takahashi, and R. Wanninkhof, Uptake and storage of carbon dioxide in the ocean: The global CO_2 survey, *Oceanography*, *14* (4), 18-32, 2001.

Gloor, M., N. Gruber, T.M.C. Hughes, and J.L. Sarmiento, Estimating net air-sea fluxes from ocean bulk data: Methodology and application to the heat cycle, *Global Biogeochemical Cycles*, *15* (4), 767-782, 2001.

Takahashi, T., S.C. Sutherland, C. Sweeney, A.P.N. Metzl, B. Tilbrook, N. Bates, R. Wanninkhof, R.A. Feely, C. Sabine, J. Olafsson, and Y. Nojiri, Global air-sea CO_2 flux based on climatological surface ocean pCO_2, and seasonal biological and temperature effects, *Deep-Sea Research II*, *49*, 1601--1622, 2002.

Wanninkhof, R., Relationship between wind speed and gas exchange over the ocean, *Journal of Geophysical Research*, *97* (C5), 7373--7382, 1992.

Wanninkhof, R., and W.R. McGillis, A cubic relationship between air-sea CO_2 exchange and wind speed, *Geophysical Research Letters*, *26* (13), 1889--1892, 1999.